Distinct Differences in Precipitation Mercury Concentrations Between Urban and Rural Measurements

David A. Gay[1], Eric Prestbo[2], Brian Kerschner[1]
1 National Atmospheric Deposition Program, Illinois State Water Survey, University of Illinois, 2204 Griffith Drive, Champaign, IL 61820 USA, (217) 244 – 0462, dgay@illinois.edu; 2 Tekran Instrument Corp.

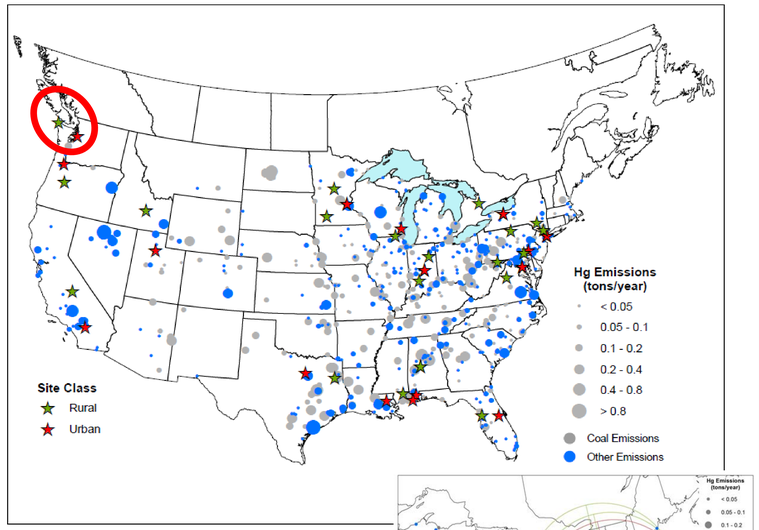
National Atmospheric Deposition Program
ILLINOIS

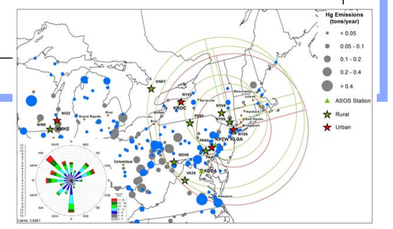
ABSTRACT

Mercury (Hg) is widely recognized as a toxic pollutant of global importance, with impacts on health for both humans and wildlife. Through the use of network data from the Mercury Deposition Network, we compared 15 urban and rural site pairs for differences in Hg concentration and wet deposition fluxes in precipitation. We postulated that urban environments have multiple small point and area sources resulting in higher local Hg emissions and thus higher deposition rates. Given the near proximity of these urban/rural pairs, precipitation is generally equal, allowing for a more direct comparison of wet deposition.

Data from the MDN for years 1996 through 2011 were used to compare precipitation concentration and deposition at 15 urban and rural locations typically within 100 miles of each other. For pairwise, week-to-week concentration and deposition comparisons, 2052 weeks were available for analysis. Several significant results were found, including urban sites have higher concentrations of Hg in precipitation than the corresponding rural site at 95% certainty, that approximately two thirds of the time (with equal precipitation) an urban site has both higher Hg concentrations and higher deposition of Hg than a surrounding rural site, and that the difference is typically about 1 and 2 ng/L across all U.S. sites (10 to 20%). Reasons for these differences will be discussed, including when higher Hg emissions at urban locations occur; however, higher emissions are not always the case. Some observations suggest that urban photochemistry may be playing an important role in higher urban deposition. These results will have important policy ramifications for urban areas and mercury policy in general.

Urban & Rural Site Pairs, Mercury Emissions



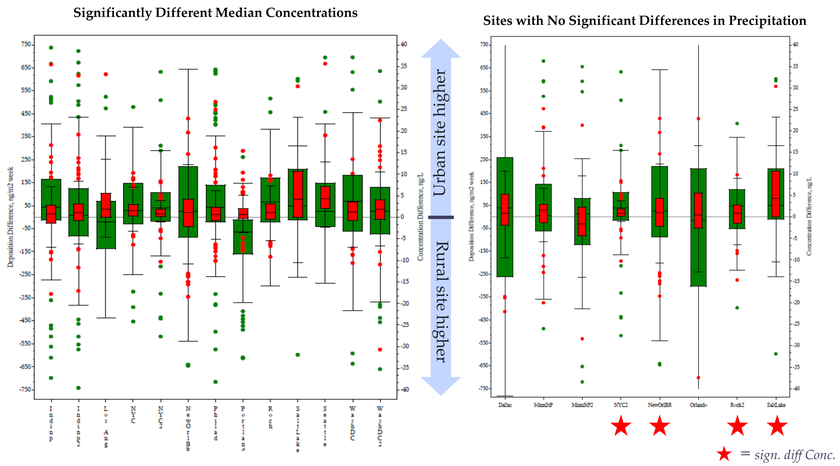


Example of winds and emissions summation

Statistical Results

Urban Rural Pair	NADP Site ID	n Pairs	Mean Diff.	Median Diff.	t-test of mean*			Wilconxon Test of Median		Precipitation Difference (diff in mm)	
	urb_rur		ng/L	ng/L	t value	p value	Sh-Wil stat	Sign. Stat	p value	median diff	p value
All Sites		2052	1.40	0.92	9.26	0.00	n	314074	0.00	-0.25	0.04
Dallas/Ft. Worth	*TX_50_21*	47	0.16	0.80	0.16	0.87	n	100	0.29	1.27	0.98
Indianapolis	*IN_26_20*	121	1.05	0.83	2.09	0.04	n	865	0.02	3.05	0.02
Indianapolis #2	*IN_26_28*	146	2.14	1.09	2.67	0.01	n	1868	0.00	-3.05	0.04
Los Angeles	*CA_94_75*	39	3.48	1.80	3.35	0.00	n	256	0.00	-25.40	0.00
Milwaukee	*WI_22_99*	130	1.13	0.11	1.33	0.19	n	285	0.51	-2.79	0.02
Minn/St. Paul	*MN_98_23*	52	1.41	1.51	1.37	0.18	n	206	0.06	-3.43	0.45
Minn/St. Paul #2	*MN_98_27*	43	-1.54	-1.63	-1.36	0.18	n	-121	0.15	0.25	0.71
Mobile	*AL_02_03*	165	0.79	0.16	1.85	0.07	n	1107	0.07	9.65	0.00
Mobile #2	*AL_24_03*	162	0.38	-0.27	0.84	0.40	n	101	0.87	7.24	0.00
New Orleans/BR.	*LA_28_22*	169	1.56	1.04	2.23	0.03	n	1696	0.01	0.00	0.89
New York City	*NY_06_68*	96	1.82	1.53	6.38	0.00	n	1623	0.00	-4.70	0.05
New York City #2	*NY_06_99*	61	0.95	0.84	2.86	0.01	n	582	0.00	3.05	0.23
Orlando	*FL_32_05*	69	1.05	0.40	1.08	0.28	n	257	0.13	-2.54	0.17
Philadelphia	*PA_60_47*	169	0.99	0.55	2.70	0.01	n	1834	0.00	3.43	0.00
Portland	*OR_01_10*	103	0.89	0.55	2.79	0.01	n	1074	0.00	-32.26	0.00
Rochester	*NY_43_07*	70	1.08	1.09	2.38	0.02	non-n	466	0.01	8.00	0.00
Rochester #2	*NY_43_90*	73	0.44	0.88	0.92	0.36	n	250	0.16	5.08	0.06
Salt Lake City	*UT_97_03*	20	6.57	4.23	3.02	0.01	non-n	76	0.00	0.76	0.39
Seattle	*WA_18_03*	65	5.89	4.31	6.33	0.00	n	1035	0.00	-33.27	0.00
Washington DC	*MD_99_08*	121	1.26	1.29	3.39	0.00	non-n	1392	0.00	4.83	0.04
Washington DC #2	*MD_99_28*	131	2.64	1.84	3.34	0.00	n	2284	0.00	-2.54	0.02

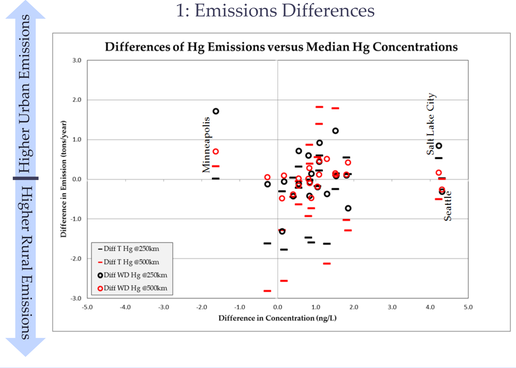
Summary Statistics for statistical tests of wet deposition mercury concentration (urban – rural) and for precipitation depth, as measured at urban and rural locations. Green boxes are positive differences or significant at 95% confidence; red boxes are negative differences. The Shapiro-Wilcoxon column is either normally or non-normally distributed (n or non-n), and grey box observation violate statistical assumptions and therefore suspect.



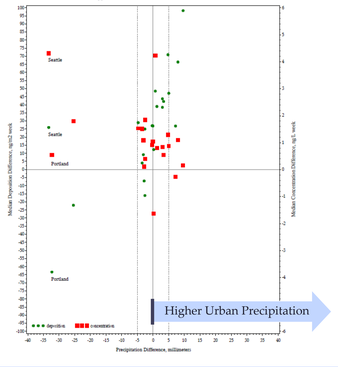
Concentration Deposition

Discussion: What is driving this difference? There are many potential reasons. Graph 1 shows that local emissions are not higher near the urban site as expected, but can be higher either around the urban or the rural site. Graph 2 shows that precipitation can be higher at either rural or urban site, so there is no consistent dilution/concentration effect occurring. Graph 3 shows that the concentration differences are higher during the warm summer months, suggesting that photochemistry in the urban areas may be producing the higher mercury concentrations in the atmosphere, and therefore in precipitation.

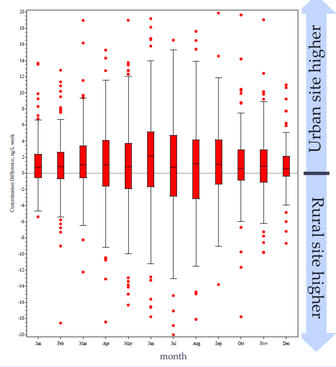
1: Emissions Differences



2: Precipitation Differences



3: Temperature Differences



CONCLUSIONS

Mercury concentrations in precipitation are clearly higher in urban environments, as seen at urban/rural pairs of Mercury Deposition Network sites. This is consistent with model predictions.

This difference is statistically significant at 13 of 21 pairs over 15 years of observations (table).

This mercury concentration differences occurs:

- with and without significant precipitation differences (Graph 2);
- with and without higher urban emissions of mercury (total Hg, Graph 1); and
- and is higher (median) in the warmer months (Graph 3), which suggests that higher photochemistry rates could be driving this difference, since higher photochemical rates would be expected around the more-urban areas.

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